A Minor Modification of Leading Edge Discriminator Circuitry with a Delay Line for Baseline Restoration of Scintillation Detectors

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(1)   Background

Multi-channel neutron time-of-flight detector arrays LaNSA[1], T-ion[2], Medusa[3], and Mandala[4], have been used for neutron spectroscopy in inertial confinement fusion experiments. These multi-channel neutron detector arrays consist of many identical scintillation detectors (842~1024 channel), data acquisition electronics (discriminators, time-to digital converters, and controller). Each detector element is operated in neutron counting mode. Time-of-flight of individual detected neutrons are recorded by time to digital converters. The energy of each detected neutrons is determined from its time-of-flight. The accurate time measurement ($\Delta t \sim 0.5$ ns) and straightforward statistical features of the data obtained with these systems provides good integrity and reliability.

The elements detector used in these systems are organic scintillators coupled with photo multiplier tubes. A scintillation detector operated in particle-counting mode requires finite recovery time after each detection event. The recovery time is determined by the time responses of scintillators, photo multiplier tubes, and the dead times of following discriminators and time-to digital converters.

The harsh gamma ray background environment of fast ignitor experiments requires detectors that have fast recovery times [5]. In high intensity laser experiments ($I > 10^{19}$ W/cm^2), strong gamma ray bursts are produced by relativistic laser plasma interactions. Prior to the neutron signal, these strong gamma ray bursts hit the detectors and interfere with the detection of following neutron signals. In these situations, the recovery time of the system after preceding gamma ray bursts is determined mainly by the base line shift of the PMT signal (due to slower decay components of scintillators "after glow"). Discriminators cannot detect following signal pulses until the proceeding burst decays below its threshold voltage. The base line shift caused by the after glow prolongs the recovery time of the discriminators. Typical organic scintillators have slow decay component with 300~600 nsec [6,7] .
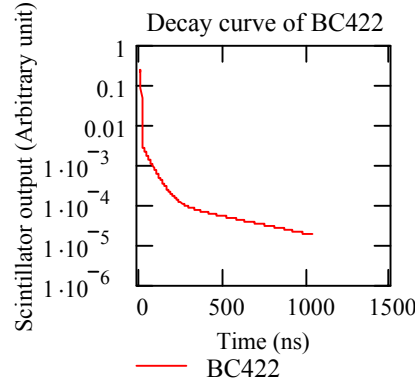

Figure 1. Scintillation decay curve of Bicron BC422 plastic scintillator [6,7].

An areal density measurement with the downshifted neutron method also requires scintillation detectors that have fast recovery time[8]. Prior to the downshifted neutron signal, a strong burst of primary neutrons hits the detectors and interferes following detection of downshifted neutrons. The technique proposed here is also applicable to the downshifted neutron measurement with a multi-channel neutron detector array.

(2)   Base line restoration with delay line

Assuming that the dynode circuitry of photo multiplier tube is not totally discharged by primary burst of gamma ray or neutrons, the suppression of the base line shift can be done with a minor modification of discriminator circuitry. Figure 2 shows a schematic of discriminator circuitry. By replacing the 50-ohm terminator of discriminator input circuitry with a delay line of adequate length (eg. coaxial cable), the scintillation signal will be reflected on shorted end of the line and added to the input signal. Since the polarity of the reflected pulse is inverted, the discriminator input is converted to a bipolar pulse.
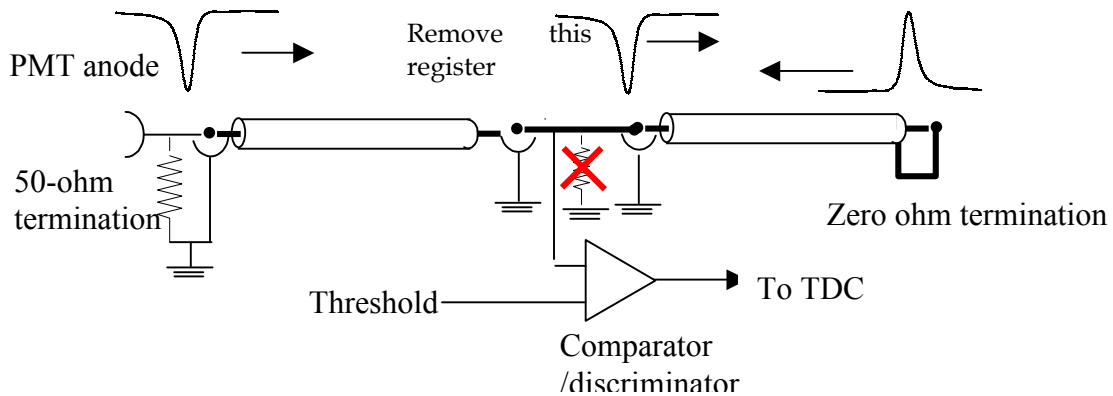

Figure 2. Schematic of baseline restoration with delay line. The photo-multiplier anode has to be terminated with 50-ohm register to suppress pulse reflection on detector side.

For example, if 100 cm coaxial line is used as a delay line, the pulse round-trip transit time is ~10 ns. Figure 3 shows the expected impulse response of the detector with and with out base line restoration. The reflected pulse will make a bipolar signal that has 10ns time interval between leading negative peak and following positive peak. The after glow component which has decay time $\tau > 10$ ns will be cancelled out.
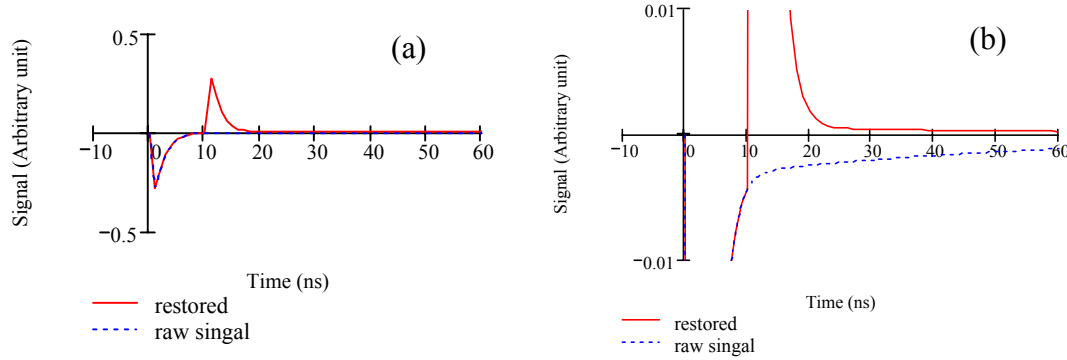
Figure 3. Comparison of calculated raw signal and baseline restored bipolar signal: (a) entire shape of the raw and the restored signal, (b) detailed detector response around zero cross point.

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